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Patentanmeldung Nr. Patent application No. Demande de brevet n°

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R C van Dijk



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Process for the preparation of a polyolefin

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PROCESS FOR THE PREPARATION OF A POLYOLEFIN

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The invention relates to a process for the preparation of a polymer of at least one aliphatic or aromatic hydrocarbyl C_{2-20} mono- or multiolefin in the presence of a catalyst and a boron comprising co-catalyst.

10 Such a process is described in WO 98/49212.

WO 98/49212 describes the preparation of a polymer of one or more aliphatic or aromatic hydrocarbyl C_{2-20} mono- or diolefins in the presence of a catalyst consisting of a metal-organic compound and a boron comprising co-catalyst. A boron comprising co-catalyst is used because of the high reactivity of the catalyst system
15 described in WO 98/49212 in combination with a boron comprising co-catalyst.

Disadvantage of the process described in WO 98/49212 is the use of an expensive catalyst, which requires several reaction steps for its production. These processes require at least four steps: (i) reaction of a ligand with a strong base resulting in a metal-organic salt of this ligand, followed by (ii) contacting this salt with a
20 metal-organic reagent resulting in a metal-organic compound which has to (iii) be hydrocarbylated and (iv) further contacted with a borane or borate in order to form the active species. For some catalysts an additional oxidation step after the formation of the metal-organic compound is needed using an oxidizing agent.

An aim of the invention is to provide a process for the preparation of
25 a polymer comprising one or more aliphatic or aromatic hydrocarbyl C_{2-20} mono- or multiolefins in the presence of a boron comprising co-catalyst and a catalyst, which can be formed in situ in the polymerization equipment.

This aim is achieved in the process of the invention by a catalyst, which comprises a composition of a spectator ligand, a metal-organic reagent, and
30 optionally at least one equivalent of a hydrocarbylating agent.

By the process of the invention a polymerization of one or more aliphatic or aromatic hydrocarbyl C_{2-20} mono- or multiolefins in the presence of a boron comprising co-catalyst can be carried out in the presence of a catalyst, which is formed in situ in the polymerization equipment.

35 Processes for the preparation of a polymer of at least one aliphatic or aromatic hydrocarbyl C_{2-20} mono- or multiolefins are fairly well known in the art. These processes are generally conducted by contacting at least one mono-, or multiolefinic

monomer with a catalyst in the presence of an inert hydrocarbon solvent. Examples of an inert hydrocarbon solvent are a C₅₋₁₂ hydrocarbon which may be substituted by an C₁₋₄ alkyl group, such as pentane, hexane, heptane, octane, cyclohexane, methylcyclohexane and hydrogenated naphtha. The process of the invention may be conducted at temperatures from about 20° C to about 250° C, depending on the product being made.

A mono-olefinic monomer is understood to be a molecule containing a polymerizable double bond, optionally containing a polar functional group. A multiolefinic monomer is understood to be a molecule containing at least two polymerizable double bonds, optionally containing also a polar functional group.

Suitable mono-olefin monomers may be ethylene or C₃₋₂₀ monoolefins. Preferred monomers include ethylene and C₃₋₁₂ alpha olefins which are unsubstituted or substituted by up to two C₁₋₆ alkyl radicals, C₈₋₁₂ vinyl aromatic monomers which are unsubstituted or substituted by up to two substituents selected from the group consisting of C₁₋₄ alkyl radicals, C₄₋₁₂ straight chained or cyclic hydrocarbyl radicals which are unsubstituted or substituted by a C₁₋₄ alkyl radical. Illustrative non-limiting examples of such alpha-olefins are one or more of propylene, 1-butene, 1-pentene, 1-hexene, 1-octene, and 1-decene, styrene, alpha methyl styrene, p- t-butyl styrene, and the cyclic olefins such as cyclobutene, cyclopentene, norbornene, alkyl-substituted norbornenes. Suitable multiolefins include C₄-C₃₅ multiolefins. The double bonds may be conjugated or not conjugated, endo- and or exocyclic and may have different amounts and type of substituents. Examples of such multiolefins include 1,3-butadiene, isoprene, 1,4-hexadiene or 1,6-octadiene, divinylbenzene; monocyclic or polycyclic dienes, for example 1,4-cyclohexadiene, alkenyl-substituted norbornenes and the like (e.g. 5-methylene-2-norbornene and 5-ethylidene-2-norbornene, 5-vinylnorbornene, and bicyclo-(2,2,1)-hepta-2,5-diene), dicyclopentadiene, vinylcyclohexene and the like.

Homo-, co- and ter-polymers of the above mentioned mono- and multimonomers and blends thereof can be prepared with the present invention.

Other olefin polymers which may be prepared in accordance with the present invention may be determined by one of ordinary skill in the art using non-inventive testing.

In the process of the invention a boron comprising co-catalyst is used. A boron comprising co-catalyst is understood to be a cocatalyst as described in *Chem. Rev.*, 2000, 100, 1391 by E. Y-X. Chen and T.J. Marks.

In the process of the invention the metal-organic reagent can be represented by formula 1:



with M being a metal from group 3-11, X a monoanionic ligand bonded to M, L a
5 neutral Lewis basic ligand bonded to M, j representing an integer denoting the number
of neutral ligands L and p is the valency of the metal M.

Examples of Lewis basic ligands include ethers, such as
tetrahydrofuran (THF), diethylether, thioethers, like thiophene, diethylsulfide,
dimethylsulfide, amines, such as trialkylamines, pyridine, bipyridine, TMEDA, (-)-
10 sparteine), phosphanes and diphosphanes, such as triphenylphosphine,
trialkylphosphanes, bidentate alkyl or arylidiphosphanes). The amount of ligands (X and
L) depends on the valency of the metal and the stability of the metal-organic reagent.
The metal-organic reagent may be monomeric, oligomeric or a cluster. The number of
anionic ligands equals the valency of the metal used. The number of neutral ligands on
15 the metal-organic reagent may range from 0 to the amount that satisfies the 18-
electron rule, as known in the art.

Each anionic ligand, X, may be independently selected from the
group consisting of monoanionic spectator ligands, hydride, halide, alkyl, silyl, germyl,
aryl, amide, aryloxy, alkoxy, phosphide, sulfide, acyl, pseudo halides such as cyanide,
20 azide, acetylacetonate, etc., or a combination thereof. Preferably, X is hydride or a
moiety selected from the group consisting of monoanionic spectator ligands, halide,
alkyl, aryl, silyl, germyl, aryloxy, alkoxy, amide, siloxy and combinations thereof (e.g:
alkaryl, aralkyl, silyl substituted alkyl, silyl substituted aryl, aryloxyalkyl, aryloxyaryl,
alkoxyalkyl, alkoxyaryl, amidoalkyl, amidoaryl, siloxyalkyl, siloxyaryl, amidosiloxyalkyl,
25 haloalkyl, haloaryl, etc.) having up to 20 non-hydrogen atoms.

The process of the invention is optionally carried out in the presence
of at least one equivalent of an hydrocarbylating agent. In the process of the invention
hydrocarbylating agents are nucleophilic groups comprising a metal-, or a metalloid-
carbon or hydride bond. The number of equivalents required for the process of the
30 invention depends on the amount and the type (mono-, or dianionic) of the spectator
ligand.

Examples of hydrocarbylating agents are: tri-, or tetrahydrocarbyl
boron, tri-, or tetrahydrocarbyl aluminium, tri-, or tetrahydrocarbyl gallium, tri-, or
tetrahydrocarbyl indium and di-, or tetrahydrocarbyl tin, or the reaction products of
35 these hydrocarbylating agents with sterically hindered alcohols, thiols, amines or
phosphanes.

Preferably the hydrocarbylating agent comprises a metal or a

metalloid chosen from group 1, 2, 11, 12, 13 or 14. Examples of hydrides from metals or metalloids of group 1, 2, 11, 12, 13, 14 include: lithiumhydride, sodiumhydride, potassiumhydride, calciumhydride, magnesiumhydride, copperhydride, zinchydride, cadmiumhydride, borane, aluminumhydride, galliumhydride, siliconhydride, germaniumhydride, and tinhydride.

Preferably the hydrocarbylating agent comprises Li, Mg, Zn, or Al.

Examples of Li comprising hydrocarbylating agents are methyllithium, phenyllithium, benzylolithium, biphenyllithium, naphtyllithium, lithio-dimethylresorcinol, and lithio-N,N-dimethylaniline.

Examples of magnesium comprising hydrocarbylating agents are methylmagnesiumhalide, phenylmagnesiumhalide, benzylmagnesiumhalide, biphenylmagnesiumhalide, naphtylmagnesiumhalide, tolylmagnesiumhalide, xylylmagnesiumhalide, mesitylmagnesiumhalide, dimethylresorcinolmagnesiumhalide, N,N-dimethylanilinemagnesiumhalide, dimethylmagnesium, diphenylmagnesium, dibenzylmagnesium, (biphenylene)magnesium, dinaphtylmagnesium, ditolylmagnesium, dixylylmagnesium, dimesitylmagnesium, bis(dimethylresorcinol)magnesium, and bis(N,N-dimethylaniline)magnesium.

Examples of aluminium comprising hydrocarbylating agents are diisobutylaluminium hydride, C₁-C₂₀ trihydrocarbyl aluminium, and hydrocarbylaluminoxanes.

To facilitate the process of the invention, the process may be carried out in the presence of a base other than a hydrocarbylating agent. Examples of such bases include, amines, phosphanes, carboxylates (for example potassium acetate), hydroxides, cyanides, amides and carbonates of Li, Na, K, Rb, Cs, ammonium and the group 2 metals Mg, Ca, and Ba, the alkali metal (Li, Na, K, Rb, Cs) phosphates and the phosphate esters (eg. C₆ H₅ OP(O)(ONa)₂ and related aryl and alkyl compounds) and their alkoxides and phenoxides, thallium hydroxide, alkylammonium hydroxides, hydrides of from metals or metalloids of group 1, 2, 11, 12, 13, 14. Also the metallic alkalimetals of group 1 may be applied as a base.

In the process of the invention a spectator ligand is chosen from a monoacidic spectator ligand, a diacidic bidentate spectator ligand, a monoacidic bidentate spectator ligand, or a Lewis basic bi-, or multidentate spectator ligand.

An example of a mono acidic spectator ligand is an imine ligand according to formula 2, or the HA adduct thereof, wherein HA represents an acid, of which H represents its proton and A its conjugate base,

Y=N-R

(formula 2),

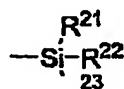
wherein Y is selected from a substituted carbon, nitrogen or phosphorous atom and R represents a substituent. If Y represents a substituted carbon atom, the number of substituents is 2. If Y represents a substituted nitrogen atom, the number of substituents is 1 and the number of substituents is 1 or 3 if Y represents a phosphorous atom, depending on the valency of the phosphorous atom.

Substituents on carbon, nitrogen or phosphorous may be equal or different, optionally linked with each other, optionally having hetero atoms. Substituents may be protic or aprotic.

A protic substituent is defined here as a substituent which has at least one group 15 or group 16 atom containing at least one proton.

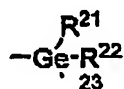
Examples of protic substituents include C₁-C₂₀ linear, branched or cyclic hydrocarbyl radicals, substituted with a group 15 or 16 atom bearing at least one hydrogen atom. Preferred protic substituents include phenolic radicals, pyrrolic radicals, indolic radicals, and imidazolic radicals.

The substituent is called aprotic if the substituent lacks a group containing a group 15 or group 16 atom bearing a proton. An unsubstituted aprotic hydrocarbyl radical can be a C₁-C₂₀ linear, branched or cyclic radical, a hydrogen atom, a halogen atom, a group 14 oxy radical - such as a C₁₋₈ alkoxy radical, a C₈₋₁₀ aryl or aryloxy radical, silyloxy radical, germanyloxy radical, stannyloxy radical - an amido radical, or a C₁₋₂₀ hydrocarbyl radical unsubstituted or substituted by a halogen atom, a C₁₋₈ alkoxy radical, a C₈₋₁₀ aryl or aryloxy radical, an amido radical, a silyl radical of the formula:



(formula 3)

or a germanyl radical of the formula:



(formula 4)

wherein R^{2j} with j = 1 to 3 is independently selected from the group consisting of hydrogen, a C₁₋₈ alkyl or alkoxy radical, C₈₋₁₀ aryl, aryloxy radicals a silyl radical of formula 3 or a germanyl radical of formula 4, each substituent R^{2j} may be linked with another R^{2j} to form a ring system.

The substituent R can be H, or being equal as these for the substituent on Y.

Examples of imine ligands according to formula (2) include: guanidines, iminoimidazolines, phosphinimines, phenolmines, pyrroleimines, indoleimines and imidazoleimines.

R may be linked with Y, thus forming a ring system, optionally comprising hetero atoms, or optionally comprising functional groups. Examples of ligands comprising such ring systems include: 8-hydroxyquinoline, 8-aminoquinoline, 8-phosphinoquinoline, 8-thioquinoline, 8-hydroxyquinaldine, 8-

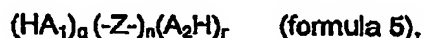
aminoquinaldine,

8-phosphinoquinaldine, 8-thioquinaldine and 7-azaindole or indazole.

In the process of the invention, HA represents an acid, of which H represents its proton and A its conjugate base. Examples of A are halogenides, (such as fluoride, chloride, bromide, or iodide), sulfate, hydrogensulfate, phosphate, hydrogenphosphate, dihydrogenphosphate, carbonate, hydrogencarbonate, aromatic or aliphatic carboxylates, cyanide, tetrafluoroborate, (substituted) tetraphenylborates, fluorinated tetraarylborates, alkyl or aryl sulfonates.

In case the HA adduct of the imine ligand is used, one more equivalent of the hydrocarbylating agent is required.

Examples of mono – or diacidic spectator ligand are ligands according to formula 5:



wherein A_1 and A_2 are monoacidic cyclopentadienyl comprising ligands (Cp), with q and r representing an integer denoting the number of Cp ligands with $q+r = 1$ or 2, optionally linked by n bridging groups Z, with n representing the number of parallel bridges Z, A_1 , A_2 when bonded via Z together forming a bidentate diacidic spectator ligand or if Z is absent A_1 , A_2 form two monoacidic spectator ligands.

The ligands A_1 and A_2 are defined as cyclopentadienyl comprising ligands. Under cyclopentadienyl comprising ligands is understood that a part of the molecular structure contains a cyclopentadienyl (Cp) ring. This ring may be substituted with at least one R' -group. When the Cp-ring is substituted with at least two R' groups, these R' groups may form ring systems. As result of that the Cp-comprising ligand may be indenyl comprising ligands or fluorenyl comprising ligands. The ligands A_1 and A_2 may be each independently selected (substituted) cyclopentadienyl groups, (substituted)indenyl groups, (substituted)fluorenyl groups, (substituted)

tetrahydroindenyl groups, (substituted) tetrahydrofluorenyl groups, (substituted) octahydrofluorenyl groups, (substituted) benzoindenyl groups, (substituted) heterocyclopentadienyl groups, (substituted) heteroindenyl groups, (substituted) heterofluorenyl groups, or its isomers. Here and in the following a hetero
5 cyclopentadienyl group (in the following also referred to as 'hetero ligand') is understood to be a group that has been derived from a cyclopentadienyl group, but in which at least one of the C atoms in the 5-ring of the cyclopentadienyl has been replaced by a hetero atom, which hetero atom may be chosen from group 14, 15 or 16. If there is more than one hetero atom present in the 5-ring of the hetero ligand, these
10 hetero atoms may be either the same or different. More preferably, the hetero atom has been chosen from group 15, while yet more preferably the hetero atom is phosphorus.

The R' groups may each independently be hydrogen or a hydrocarbon radical with 1-20 carbon atoms (e.g alkyl, aryl, biaryl, aralkyl, alkaryl and the like) or a heteroatom comprising moiety from group 13-17. Examples of such
15 hydrocarbon radicals are methyl, ethyl, n-propyl, i-propyl, butyl (including isomers), hexyl (including isomers), decyl (including isomers), phenyl, biphenyl (including isomers) and the like. Examples of heteroatom comprising moieties of group 13-17 include borane radicals, silyl radicals, germyl radicals, stannyl radicals, amide radicals, phosphide radicals, oxide radicals, sulphide radicals, halide radicals, halide substituted
20 hydrocarbyl radicals and the like. Also, two adjacent hydrocarbon radicals may be connected with each other in a ring system. Such a group as well may contain one or more R' groups as substituents. R' may also be a substituent which instead of or in addition to carbon and/or hydrogen may comprise one or more hetero atoms of groups 13-17.

25 The bridging group Z may contain sp^3 , sp^2 or sp hybridized atoms of group 13 to 16 or combinations thereof. The bridging group Z may consist of linear, cyclic fragments, spiro ring systems, or combinations thereof. Examples of a carbon containing Z group may each separately be a hydrocarbon group with 1-20 carbon atoms, e.g. alkylidene, arylene, biarylene, aryl alkylidene, etc. Examples of such
30 groups are methylene, ethylene, propylene, butylene, phenylene, naphthylene, biphenylene, binaphthylene. Examples of silicon containing groups are dimethylsilyl, diethylsilyl, dipropylsilyl, including its isomers, (substituted) diphenylsilyl, dimethoxysilyl, diethoxysilyl, dipropoxysilyl, and diphenoxysilyl.

An example of a diacidic bidentate spectator ligand or a monoacidic
35 bidentate spectator ligand is a ligand according to formula 6:



In which A_1 is a delocalized η^5 bonding cyclopentadienyl comprising ligand, Z is a moiety comprising boron, or a member of Group 14, and optionally also sulfur or oxygen, said moiety having up to 20 non-hydrogen atoms, and optionally A_1 and Z together form a fused ring system, D is a Lewis basic ligand bonded to Z comprising a group 15 or 16 atom having up to 20 non-hydrogen atoms, optionally D and Z together form a fused ring system and $b = 0$ or 1. Hereinafter a Lewis basic ligand is also referred to as a donor moiety. The mono-, or diacidic spectator ligand has 1 or 2 acidic protons, one of which is the acidic cyclopentadienyl proton. If the acidic spectator ligand contains only 1 proton (thus the cyclopentadienyl acidic proton), then b equals 0 and D is a neutral two electron donor moiety. If the acidic spectator ligand contains 2 protons, then b equals 1 and D contains an acidic proton.

Preferably D is $-O-$, $-S-$, $-NR^*$, $-PR^*$, or a neutral two electron donor moiety selected from the group consisting of OR^* , SR^* , NR^*_2 , or PR^*_2 .

Z may be SiR^*_2 , CR^*_2 , $SiR^*_2SiR^*_2$, $CR^*_2CR^*_2$, $CR^*=CR^*$, $CR^*_2SiR^*_2$, GeR^*_2 , BR^* , BR^*_2 , wherein each R^* can be independently selected from the group consisting of hydrogen, alkyl, aryl, silyl, halogenated alkyl, halogenated aryl radicals, or combinations thereof (e.g. aralkyl, alkaryl, haloalkaryl and haloaralkyl radicals) having up to 20 non-hydrogen atoms, or two or more R^* groups from Y, Z, or both Y and Z form a fused ring system.

Another example of a monoacidic bidentate ligand (SH) is a bi- or multidentate ligand, wherein S is represented by formula 7:



with,

Y represents an anionic moiety of S, Z optional bridging groups between the Y moiety and the DR'_n and/or Ar group, D a hetero atom chosen from group 15 or 16, R' an optional substituent, Ar an electron-donating aryl group, n the number of R' groups bonded to D, and q and s are integers with $q + s \geq 1$.

If the ligand is a ligand represented by $(Ar-Z)_sY(-Z-DR'_n)_q$, the transition metal is preferably chosen from groups 4-6 of the Periodic Table of the Elements. More preferably, the transition metal has been chosen from group 4, with the most preference to titanium (Ti) as transition metal. The transition metal is preferably present in reduced form in the compound, which means that the transition metal is in a reduced oxidation state (p). By 'reduced oxidation state' is meant an oxidation state which is lower than the highest possible oxidation state for a particular metal, which means at most M^{3+} for a transition metal of group 4, at most M^{4+} for a transition metal of

group 5 and at most M^{5+} for a transition metal of group 6.

Examples of Y moieties include hydrocarbyl substituted groups comprising a group 15 or 16 atom, (substituted) cyclopentadienyl, (substituted) indenyl, (substituted) fluorenyl, (substituted) heterocyclopentadienyl, (substituted) heteroindenyl, (substituted) heterofluorenyl, or imine groups. Imine groups are defined as groups containing a double bonded nitrogen atom. Examples of imine groups are ketimide, guanidine, phosphinimide, iminoimidazoline, (hetero)aryloxyimines, pyrroleimines, indoleimines, imidazoleimines or (hetero)aryloxides, (substituted) pyridin-2-yl-methoxy, (substituted) quinolin-2-yl-methoxy, 8-hydroxyquinoline, 8-aminoquinoline, 8-phosphinoquinoline, 8-thioquinoline, 8-hydroxyquinaldine, 8-aminoquinaldine, 8-phosphinoquinaldine, 8-thioquinaldine and 7-azaindole or indazole, and the like.

The optional bridging group Z may contain sp^3 , sp^2 or sp hybridized atoms or combinations thereof. The bridging group Z may consist of linear, cyclic fragments, or combinations thereof. The Z groups may each separately be a hydrocarbon group with 1-20 carbon atoms, e.g. alkylidene, arylene, aryl alkylidene, etc. Examples of such groups are methylene, ethylene, propylene, butylene, biphenylene, binaphtylene, phenylene, whether or not with a substituted side chain, linear or cyclic.

Besides carbon, the main chain of the Z group may also contain larger members of group 14, such as silicon, germanium or tin. Examples of such Z groups are: dialkyl silylene, dialkyl germylene, tetra-alkyl disilylene or tetraalkyl silaethylene ($-SiR'_2CR'_2$).

The hetero atom containing donor group DR'_n consists of at least one group 15 or group 16 atom, or a combination thereof. Examples of donor groups include imine groups as defined above, amine groups, phosphane groups, ether groups, or thioether groups.

Also, Y, Z and D may be part of an aromatic ring system, optionally containing sp^3 , sp^2 or sp hybridized atoms or combinations thereof, together forming a spectator ligand. The D atom may thus be a part of the bridging group. In this case, the D atom containing bridging group may be further substituted by at least one optional bridging group Z containing donor groups DR'_n . Examples of spectator ligands containing aromatic ring systems having a donor atom D in the bridging group Z include (hetero)aryloxyimines, pyrroleimines, indoleimines, imidazoleimines or (hetero)aryloxides, (substituted) pyridin-2-yl-methoxy, (substituted) quinolin-2-yl-methoxy, 8-hydroxyquinoline, 8-aminoquinoline, 8-phosphinoquinoline, 8-thioquinoline,

8-hydroxyquinaldine, 8-aminoquinaldine, 8-phosphinoquinaldine, 8-thioquinaldine and 7-azaindole or indazole.

Preferably, the Y moiety may be an amido (-NR'-) group, a phosphido (-PR'-) group, an imine group, a (substituted) cyclopentadienyl group, a (substituted) indenyl group, a (substituted) fluorenyl group, a (substituted) heterocyclopentadienyl group, a (substituted) heteroindenyl group, and a (substituted) heterofluorenyl group. Here and in the following a hetero cyclopentadienyl group (in the following also referred to as 'hetero ligand') is understood to be a group that has been derived from a cyclopentadienyl group, but in which at least one of the C atoms in the 5-ring of the cyclopentadienyl has been replaced by a hetero atom, which hetero atom may be chosen from group 14, 15 or 16 of the Periodic Table of the Elements. If there is more than one hetero atom present in the 5- ring of the hetero ligand, these hetero atoms may be either the same or different. More preferably, the hetero atom has been chosen from group 15, while yet more preferably the hetero atom is phosphorus.

Preferably, the electron donor group DR'_n consists of a hetero atom D, chosen from group 15 or 16, and one or more substituents R' bonded to D. The number of R' groups is linked up with the nature of the hetero atom D, in the sense that n = 2 if D is from group 15 and n = 1 if D is from group 16. The substituent R' bonded to D is as defined. The hetero atom D has preferably been chosen from the group comprising nitrogen (N), oxygen (O), phosphorus (P) and sulphur (S); more preferably, the hetero atom is nitrogen (N) or phosphorus (P). It is further possible for two R' groups in the DR'_n group to be connected with each other to form a ring-shaped structure (so that the DR' group can be a pyrrolidinyl group). The DR' group can form coordinative bonds with M.

The aromatic electron-donating group (or donor), Ar, used can be substituted or non-substituted aryl group (C₆R'₅), such as phenyl, tolyl, xylyl, mesitylyl, cumyl, tetramethyl phenyl, pentamethyl phenyl, etc. The Ar group may also contain at least one heteroatom from group 15 or group 16. Examples of such heteroatom containing Ar groups are (substituted) pyrrole, (substituted) pyridine, (substituted) thiophene, (substituted) furan. The coordination of this Ar or heteroatom containing Ar group in relation to M may vary from η^1 to η^6 .

The R' groups may each separately be hydrogen or a hydrocarbon radical with 1-20 carbon atoms (e.g alkyl, aryl, aryl alkyl and the like). Examples of such hydrocarbon radicals are methyl, ethyl, propyl, butyl, hexyl, decyl, phenyl and the like. Also, two adjacent hydrocarbon radicals may be connected with each other in a ring system. As result from that, the Cp group may be an indenyl, tetrahydroindenyl, a fluorenyl, a tetrahydrofluorenyl, an octahydrofluorenyl or a benzoindenyl group. Such a

group as well may contain one or more R' groups as substituents. R' may also be a substituent which instead of or in addition to carbon and/or hydrogen may comprise one or more hetero atoms of groups 14-16. Thus, a substituent may be a Si-containing group.

- 5 An example of a Lewis basic bi- or multidentate ligand is a ligand according to formula 8:



- 10 wherein Z is a bridging group, between two donor atom containing groups (D),
D a group comprising a hetero atom chosen from group 15 or 16, and
R is a substituent. For all clarity, the ligand of formula 8 is not the same ligand as the
ligand (L) in the metal-organic reagent. Examples of a Lewis basic bi-, or multidentate
ligand are di-imines, tri-imines and di-imines comprising an aromatic group comprising
15 a hetero atom of group 15 or 16.

If a ligand according to formula 8 is used, the metal of the metal-organic reagent preferably is a metal from group 7-11.

- The process of the invention can be carried out in a broad variety of
polymerization equipment. It can be carried out in a single reactor, or in multiple
20 reactors, in series or parallel and combinations thereof. The process can be carried out
in gasphase, bulk, or in suspension/slurry as a batch or continuous process.

- The process of the invention is preferably carried out in a solvent.
Suitable solvents are solvents that do not react with the metal-organic reagent or the
metal-organic compound formed in the process of the invention. Examples of suitable
25 solvents include aromatic and aliphatic hydrocarbons, halogenated hydrocarbons, or
mixtures thereof.

- The process of the invention can be carried out in different ways,
which can be distinguished by the sequence in which the spectator ligand, the metal-
organic reagent, the hydrocarbylating agent and the boron comprising co-catalyst are
30 added to a polymerization reactor. Preferably the spectator ligand, the metal-organic
reagent, the hydrocarbylating agent and the boron comprising co-catalyst are each
added as a solution or a suspension to the process of the invention.

- One way is to add the spectator ligand, the metal-organic reagent, the
hydrocarbylating agent and the boron comprising co-catalyst directly to the
35 polymerization reactor.

Another way is that the spectator ligand, the metal-organic reagent and the

hydrocarbylating agent are premixed before the reactor. The advantage of premixing the spectator ligand, the metal-organic reagent and the hydrocarbylating agent is that this can be done under conditions of temperature and time different from those in the polymerization reactor, thus leading to a more active catalyst.

- 5 In this way the boron comprising co-catalyst can be added to the thus formed mixture either before the reactor or parallel to this mixture direct into the reactor. Adding the boron comprising co-catalyst to the above mentioned premixture has the advantage that an active catalyst system can be formed in a more concentrated environment than in the reactor. An even more active catalyst can be obtained by mixing the metal-
10 organic reagent with the spectator ligand before the addition of the hydrocarbylating agent.

The invention is further related to a polymer obtainable with the process of the invention and in particular obtainable with a process using a spectator ligand $(Ar-Z)_sY(-Z-DR'_n)_q$, wherein Z is an optional bridging groups between an anionic
15 moiety Y and the DR'_n and/or Ar group, D a hetero atom chosen from group 15 or 16, R' an optional substituent, Ar an electron-donating aryl group, n the number of R' groups bonded to D, q and s integers with $q + s \geq 1$ and wherein Y is an imine group. Preferably the imine is a ketimide, phosphinimide, guanidine, or iminoimidazoline. Other preferred imines are spectator ligands wherein Y, R and D are part of an
20 aromatic ring system, optionally containing sp^3 , sp^2 or sp hybridized atoms or combinations thereof. Examples of these imines include: (hetero)aryloxyimine (like (substituted) derivatives of phenoxyimines, pyrroleimines, hydroxyquinolines and the like) (hetero)arylsulphidoimine, (hetero)arylphosphidoimine and (hetero)arylamidoimine.

- 25 The invention also relates to a polymer obtainable with the process of the invention wherein Y is an imine and wherein the donor D is a ketimine, phosphinimine, guanidine, or iminoimidazoline.

The invention further relates to a polymer obtainable with the process of the invention using a spectator ligand $(Ar-Z)_sY(-Z-DR'_n)_q$, wherein Y represents an
30 anionic moiety of S, Z is an optional bridging groups between the Y moiety and the DR'_n and/or Ar group, D a hetero atom chosen from group 15 or 16, R' an optional substituent, Ar an electron-donating aryl group, n the number of R' groups bonded to D, q and s integers with $q + s \geq 1$ and, and wherein D is a ketimide, phosphinimide, guanidine, or an iminoimidazoline.

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CLAIMS

1. A process for the polymerization of at least one aliphatic or aromatic hydrocarbyl C_{2-20} mono- or multiolefin in the presence of a catalyst and a boron comprising co-catalyst, characterized in that the catalyst comprises a composition of a metal-organic reagent, a spectator ligand and optionally at least one equivalent of a hydrocarbylating agent.
2. A process according to claim 1, wherein the metal-organic reagent is represented by ML_jX_p , wherein M is a metal from group 3-11, or the lanthanide series, X a monoanionic ligand bonded to M, L a neutral ligand bonded to M, j representing an integer denoting the number of neutral ligands L and p is the valence of the metal M.
3. Process according to claim 1 or 2, wherein the hydrocarbylating agent comprises a metal or a metalloid chosen from group 1, 2, 11, 12, 13 or 14
4. A process according to claim 3, wherein the hydrocarbylating agent comprises Li, Mg, Zn, or Al.
5. Process according to claim 4, wherein the hydrocarbylating agent is a C_1-C_{20} trihydrocarbyl aluminium or aluminoxane.
6. Process according to claim 1-5, carried out in the presence of a base other than the hydrocarbylating agent.
7. A process according to claim 1-6, wherein the spectator ligand is an imine ligand, or the HA adduct thereof, wherein HA represents an acid, of which H represents its proton and A its conjugate base.
8. A process according to claim 2-7, wherein the metal-organic reagent comprises a group 4 metal and a cyclopentadienyl comprising ligand.
9. A process according to claim 1-5, wherein the spectator ligand is represented by $(HA_1)_q-Z_r-(A_2H)_n$, wherein A_1 and A_2 are monoacidic cyclopentadienyl comprising ligands, with q and r representing an integer denoting the number of Cp ligands with $q+r = 1$ or 2, optionally linked by n parallel bridging groups Z, A_1 , A_2 separately, or bonded via Z together forming a bidentate diacidic spectator ligand.
10. A process according to claim 1-5, wherein the ligand is a ligand according to the formula $HA_1-Z-D(H)_b$, in which A_1 is a delocalized η^5 bonding cyclopentadienyl comprising ligand, Z is a moiety comprising boron, or a member of Group 14, and optionally also sulfur or oxygen, said moiety having up to 20 non-hydrogen atoms, and optionally A_1 and Z together form a fused

ring system, D is a Lewis basic ligand bonded to Z and M, comprising a group 15 or 16 atom and having up to 20 non-hydrogen atoms, optionally D and Z together form a fused ring system and $b = 0$ or 1 .

11. A process according to claim 9 or 10, wherein the metal is a group 4 or group 5 metal, or a metal selected from the lanthanide series.
12. A process according to claim 1-6, wherein the ligand, represented by $(Ar-R)_s Y(-R-DR'_n)_q$, with, Y representing an anionic moiety of S bonded to M of the metal-organic compound, R an optional bridging group between the Y moiety and the DR'_n and/or Ar group, D a hetero atom chosen from group 15 or 16, R' an optional substituent, Ar an electron-donating aryl group, n the number of R' groups bonded to D, q and s integers with $q + s \geq 1$.
13. A process according to claim 12, wherein the metal is a group 4 metal with a valency of 3.
14. A process according to claim 1-5, wherein the ligand is represented by $R-D-(Z-D)_n-R$
15. wherein Z is a bridging group, between two donor atom containing groups (D), D a group comprising a hetero atom chosen from group 15 or 16, and R is a substituent.
15. A process according to claim 14, wherein the metal is a metal from Group 7 - 11.
16. Polymer obtainable with the process of claims 1-15.
17. Polymer obtainable with the process of claim 12, wherein Y is an imine group.
18. Polymer obtainable with the process of claim 17, wherein the imine is a ketimide, phosphinimide, guanidine, or iminoimidazoline.
19. Polymer obtainable with the process of claim 12 wherein D is a ketimide, phosphinimide, guanidine, or an iminoimidazoline.

ABSTRACT

- The invention related to a process for the polymerization of at least
- 5 one aliphatic or aromatic hydrocarbyl C_{2-20} mono- or multiolefin in the presence of a catalyst and a boron comprising co-catalyst, wherein the catalyst comprises a composition of a metal-organic reagent, a spectator ligand and optionally at least one equivalent of a hydrocarbylating agent. The invention further relates to a polymer obtainable by the process of the invention.